UDC 666.122.2:66.022.372:666.1.031

USE OF A PULVERIZER AS A MECHANICAL BATCH ACTIVATOR FOR GLASS MELTING

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Translated from *Steklo i Keramika*, No. 10, pp. 19 – 21, October, 2006.

The possibilities of enhancing glass melting by preliminary mechanical activation of quartz sand in a pulverizer in different conditions are examined. It was shown that mechanical activation destroys the crystal structure and increases the degree of amorphization of quartz. As a result, silicate and glass formation processes are blended in the region of lower temperatures, which decreases the glass melting temperature by 80°C.

The method of mechanical activation of solids to accelerate heterogeneous and heterophase reactions is used in many silicate technologies [1]. Positive results have been obtained in using mechanical activation as a method of physical stimulation of chemical processes and in the glass industry [2, 3].

Preliminary mechanical activation of the individual components of batches or blends before heat treatment is promising for enhancing not only the stage of solid-phase synthesis but also the entire glass melting process. This is because the glass melt and glass articles formed have their own "memory," which fixes the features of mechanical processing of the initial components in all stages of subsequent processing, since a mechanical effect on a crushed solid not only changes its dispersion but also the structure and the energy parameters of the disperse particles. When the new technology is used for obtaining a finely disperse glass batch [4], it is recommended that the traditional method of melting glass be replaced by heat treatment of the ribbon formed from mechanical activation of the raw material.

The expediency of using mechanical activation in glass technology is to a significant degree correlated with the low reactivity of silica – the basic component of the glass batch due to the physicochemical nature of silicon dioxide, that is, the presence of directed Si–O–Si covalent bonds, which are responsible for its high melting point, low volatility, and poor solubility.

However, it is especially necessary to note that the efficiency of mechanical activation is a function of the method of delivering the destructive force to the solid (impact, grinding, crushing, etc.) and the energy intensity of the process, i.e., the amount of energy transferred to the solid in the single act of destruction. There is a certain energy threshold. At low intensities of the communicated energy of the mechanical effect, however long it may be, the effect of mechanical activation cannot be attained and everything is limited by the grain (particle) dispersion. Only after the mechanical pulse reaches some defined (critical) value does mechanical activation take place.

The use of mechanical activators of the impact pulverizer type is the most promising method of activating the components of glass-melting batches. The pulverizer differs from other crushers by the short operating time of the impact element and crushed substance. For 10^{-3} sec $\leq \tau \leq 10^{-2}$ sec, the material to be crushed in the pulverizer chamber is hit by 2 to 7 powerful blows with an average duration of one blow of 10^{-3} sec $\geq \tau_0 \geq 10^{-5}$ sec. Processing of the material is intensive, where blows that rapidly follow each other do not cause dispersion of the substance s much as an increase in internal energy and correspondingly an increase in its reactivity. The larger the number of blows received by the particles, the higher the rate of the impacts ($v \geq 450$ m/sec) and the less time between impacts, then the more important the mechanical activation effect.

A DEZI 11M1 pulverizer was used for selecting the most ration conditions for mechanical activation of sand. The conditions of mechanical activation investigated are reported in Table 1.

TABLE 1

Regime	Treatments	Rotor rotation rate, sec^{-1}
1	One	50
2	″	80
3	″	120
4	Three	120
5	Five	120

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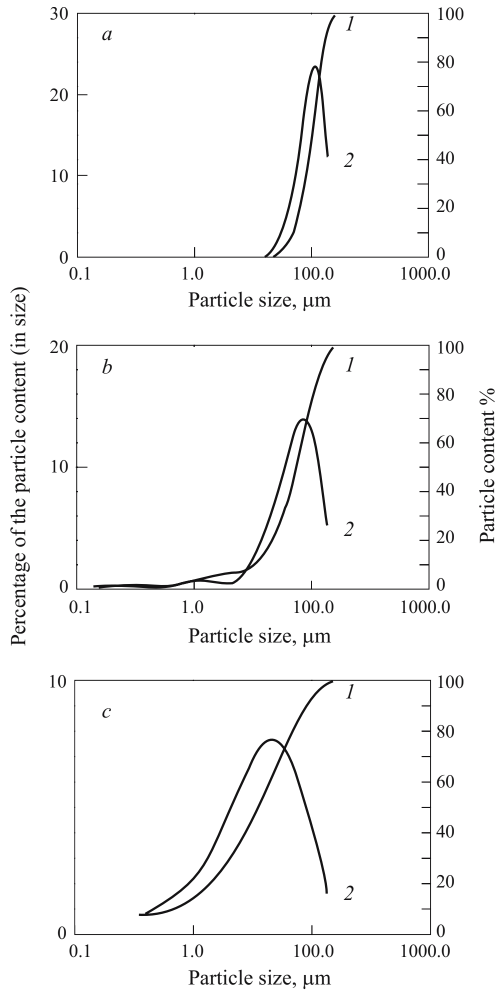

Fig. 1. Effect of the conditions of mechanical activation on the granulometric composition of sand: one treatment, rotor rotation rate (sec^{-1}): *a*) 50, *b*) 80, *c*) 120; *1* and *2*) integral and differential particle distribution curves.

The data from laser diffraction analysis (Fig. 1) indicate a change in the granulometric composition of the sand as the rotation rate of the rotor disks increased from 50 to 120 sec^{-1}. Although the amount of basic fraction 100 μm in size was at the 80% level at a rotation rate of 50 sec^{-1}, at 120 sec^{-1}, the 80 μm fraction consisted of approximately 75%, and a SiO_2 fraction smaller than 10 μm appeared. Five treatments caused lower scattering of the granulometric composition of silicon dioxide and the fraction of particles from 10 to 1 μm in size increased.

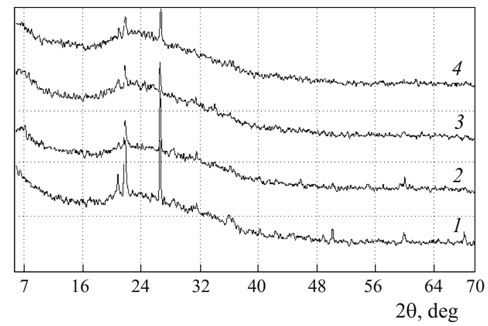

Fig. 2. X-ray spectra of initial sand (*1*) and sand activated at a rotor rotation rate of 50 (*2*), 80 (*3*), and 120 sec^{-1} (*4*).

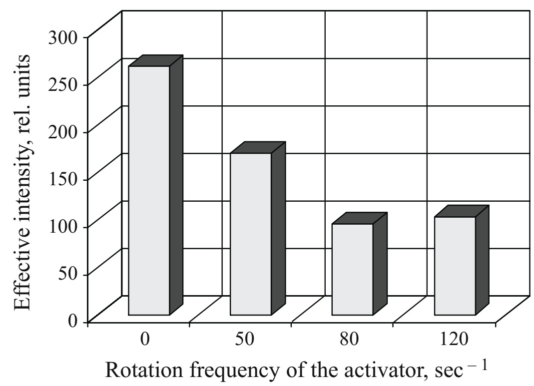

Fig. 3. Intensity of the analytical line of quartz (d = 3.336 Å) in mechanically activated sands.

Nevertheless, the degree of crushing of sand grains of different initial grain composition in the pulverizer even at a rotation rate of 120 sec^{-1} cannot be considered significant (Table 2).

The results of x-ray phase analysis of the initial quartz sand and quartz sand mechanically activated in different conditions show that an intensive impact effect on the quartz particles destroys its crystal structure. This is indicated by an increase in the halo in the region of angles $2\theta = 20 - 28°$ and shifting and a decrease in the intensity of the basic diffraction lines of quartz with d = 4.069 and 3.368 Å (Fig. 2). The most important change in the intensity of the peaks (Fig. 3) is observed in treatment of the material with a pulverizer crushing mechanism rotation rate of 80 and 120 sec^{-1}. In the last case, destruction of the crystal structure of the quartz, i.e., amorphization of the surface layers of particles, alters the

TABLE 2

Sand	Yield, %, size class, mm										
	> 4	> 2	> 1.3	> 1	> 0.6	> 0.5	> 0.3	> 0.25	> 0.15	> 0.1	< 0.1
Initial	0.74	3.15	1.47	2.40	16.80	2.32	49.45	15.58	5.04	1.00	1.00
Activated	0.06	2.02	1.57	4.64	21.55	0.90	46.27	13.82	5.08	1.79	2.30
Initial	6.50	10.95	2.34	8.40	15.57	7.14	27.28	9.34	8.83	2.89	0.76
Activated	1.64	2.79	1.28	2.40	11.20	7.90	34.52	13.26	12.32	6.66	6.03

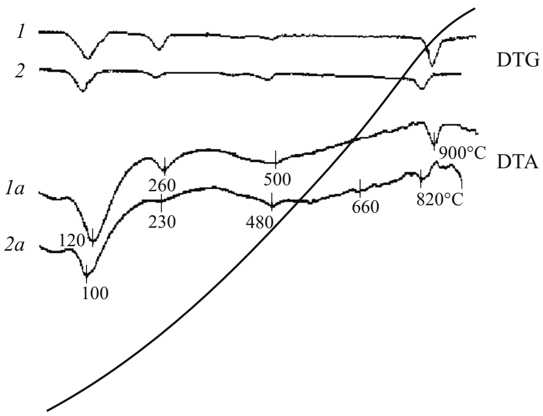

Fig. 4. Thermograms of batches with initial (*1* and *1a*) and mechanically activated sand (*2* and *2a*).

shape of the diffraction peaks in the x-ray diffraction patterns. The diffraction maxima became blurred, as the increase in the peak half-width at its half-height increased from 0.19 in the initial to 0.28 in the activated sand.

In three treatments (120 sec^{-1}), the spectrum of the sample remained identical to the sample treated once.

The mechanically activated sand was used for preparing batches of the composition (mass content, %): 72.5 – 73.0 sand, 13.2 – 13.5 soda, 8.5 – 9.0 chalk, 3.5 magnesium carbonate, and 1.0 alumina.

The initial raw material mixture contained silica which could not be processed in the pulverizer. Sand treated once in the pulverizer with a rotor rotation rate of 50, 80, and 120 sec^{-1} and three times at a rotation rate of 120 sec^{-1} was added to other batches. Thermograms corresponding to batches made with the initial sand and sand treated by regime 4 (120 sec^{-1}) are shown in Fig. 4.

All reactions in the batch with activated silica are evidently shifted toward lower temperatures. The lack of pronounced peaks indicates the smoother occurrence of the onset of all kinds of chemical reaction and the appearance of liquid phase in the batch treated three times is identified at 80°C lower than for the traditional batch.

The melting properties of the batches were evaluated by x-ray phase analysis. The residual amount of silica in the cakes of batches undergoing heat treatment served as the criterion. For this purpose, the intensity of the x-ray diffraction peaks of quartz and cristobalite in the samples after heat treatment at 1300°C and holding for 1 h was compared with the intensity of the peak of standards.

The analysis of the XPA data indicates that the largest amount of undissolved and unreacted SiO_2 is contained in the cake with untreated silica and the lowest amount is found in the cakes in batches containing silica treated in the pulverizer three times (120 sec^{-1}). The crystalline SiO_2 content in the cakes of batches treated one and three times at a rotor rotation rate of 120 sec^{-1} differed little. Mechanical activation of the sand in the pulverizer actually allowed halving the amount of undissolved silica.

The use of silica mechanically activated in the pulverizer in glass batches causes more intensive occurrence of the processes that take place in heating and in the final analysis, decreases the melting temperature and correspondingly saves energy.

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